LIBRARY
MAR 1 1 1981
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

MANUAL OF SMALL-SCALE RESERVOIR FISH CULTURE

Compiled by

Zhiwen Song
Inland Water Resources and Aquaculture Service
Fishery Resources and Environment Division

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, April 1980

PREPARATION OF THIS DOCUMENT

The preparation of this Manual was based mainly on material from The People's Republic of China. Additional information was obtained from published and unpublished literature available in the FAO Fisheries Department Library.

It is hoped that this Manual will encourage the extension of fish culture to reservoirs.

Any comments, suggestions and recommendations are welcome for a future revision of this Manual.

For bibliographic purposes, this document should be cited as follows:

Song, Z., 1980 Manual of small-scale reservoir fish culture. FAO Fish.Circ., (727):18 p.

W/M7228

FAO Fisheries Circular (FAO Fish.Circ.)

A vehicle for distribution of short or ephemeral notes, lists, etc., including provisional versions of documents to be issued later in other series.

CONTENTS

		Page
1.	INTRODUCTION	1
2.	RESERVOIRS	1
3.	FEATURES OF RESERVOIRS	2
4.	STARTING WITH THE SMALL RESERVOIRS	5
5.	PREPARATION FOR FISH CULTURE	5
6.	SPECIES AND SPECIES COMBINATIONS	8
7.	FINGERLINGS	12
8.	FEEDING THE FISH IN RESERVOIRS	14
9.	MANAGEMENT	15
10.	HARVESTING	15
11.	UTILIZATION OF MEDIUM AND LARGE RESERVOIRS	17
12.	BAY AND COVE CULTURE	18
13.	DEVELOPMENT	18

1. INTRODUCTION

Human society makes continuous progress, but raising levels of nutrition and the standard of living of the people still have a long way to go. Fisheries, including fishing and aquaculture, are almost as old as civilization itself. Aquatic products provided a great part of high protein food for mankind over the ages. During the 1970s world fisheries have undergone a radical change. Since the early seventies the annual catch has hovered around the 70 million tons mark. As the world catch slowly approaches its peak, the opportunities for increasing production are limited. Aquaculture increasingly shows its great potential for raising the world aquatic production in the future. From hunting the wild animals to animal husbandry, from picking wild fruits to farming are laws of development of history. To promote and develop aquaculture is a strategic plan in fisheries development. But, unfortunately, in most cases the importance of aquaculture has not been fully recognized and its development has not been pursued.

Reservoir fish culture is a new area of aquaculture. Very few systematic attempts have been made to sum-up and spread experience in this field. It is hoped that this Manual will encourage an increasing number of fishery scientists, technicians, extensionists, administrators, planners, fishfarmers and industrialists to pay more attention to this area and speed-up development of reservoir fish culture. It is not only of concern the increase of fish production; the matter of utmost concern is to integrate rural development and relieve the social and economic distress of millions of people. There is so much work to do, and it surely has a very bright future.

2. RESERVOIRS

Labour creates the world. The face of the world has changed considerably. There are thousands of reservoirs - man-made lakes - built on the earth and no doubt more and more reservoirs will be established.

Effects of reservoirs

Few of man's modifications of the landscape can initiate such profound physical (also chemical and biological), economic and social changes as reservoirs. They regulate and enlarge rivers and streams to make them satisfy man's general thirst for water, or his more specific needs for irrigated agriculture and power. In most cases, there are also subsidiary benefits in, for example, health, navigation and tourism. Reservoirs therefore play a vital role in human life.

The purpose of reservoirs

A reservoir may store water to its capacity, and may also produce power, allow irrigation, or serve other needs. But most of them are initially conceived for a limited number of purposes. Normally, these include one or more of the following:

- generation of electricity
- water storage for irrigation, industrial or domestic use
- flood control
- regulation of flow for navigation

Why not culture fish in the reservoirs?

It is well-stated in a Chinese saying, "Wherever there is water, there should be fish". Most of the smaller reservoirs have great possibilities for fish culture. As a matter of fact, a continuing supply of fish to provide protein-rich human food and for establishing commercial fish production can be achieved through early planning, along with other multi-purpose uses of reservoirs. In many cases, fish culture is one of the earliest and most easily achieved benefits.

3. FEATURES OF RESERVOIRS

Features of reservoirs include size, shape, latitude and altitude, hydrology and limnology. Engineers, agriculturists, soil conservationists and fishery scientists put different emphases on the relative importance of these features according to their own interests. From the fish culture point of view, reservoirs have their own particular features, which will be described below.

Size of the reservoir

The sizes of the reservoirs vary considerably. Some of them are very big, having a water area of thousands of hectares with a large water capacity, constructed mainly for power, but most of them are medium or small-size reservoirs built mainly for irrigation. From the irrigation point of view, according to the water capacity, reservoirs can be classified as:

- large-scale reservoirs (storage capacity more than 10^8 m^3)
- medium-scale reservoirs (storage capacity 10^7 - 10^8 m^3)
- small-scale reservoirs (storage capacity 10^5 - 10^7 m^3)
- ponds (storage capacity less than 10^5 m^3)

But, from the fish culture point of view, according to the water areas, reservoirs may be classified as follows:

- large-size reservoirs : greater than 1 000 ha
- medium-size reservoirs : 100 - 1 000 ha
- small-size reservoirs : less than 100 ha

At present, owing to management problems, the large and medium-size reservoirs are mainly managed by stocking to increase the natural production in the reservoirs. Many develop natural stocks quickly, being populated from the flooded river. Experience to date indicates that there is great potentiality for fish culture in small-size reservoirs. In this paper emphasis will be given to managing these.

Shape of the reservoirs

According to the shape, reservoirs can be classified in three main types:

(a) lake-type

(b) river-type

(c) multi-branched type

The lake-type, situated on flat land, generally has a slight gradient and a relatively large shallow water area, and the land around the reservoir is gently sloping. The water temperature can vary widely, but in springtime it rises rapidly making conditions suitable for fast plankton production, which in turn aids rapid fish growth and high annual fish production.

River-type reservoirs which are found in mountainous regions have a gradient which is steeper than that of flat land lake-type reservoirs; they also have steeper banks. River-type reservoirs are characterized by having a relatively low water temperature and the nutrients are not uniformly distributed: these two phenomena may adversely affect plankton growth. Generally, in this type of reservoir, fish have a slow growth rate and production is relatively low.

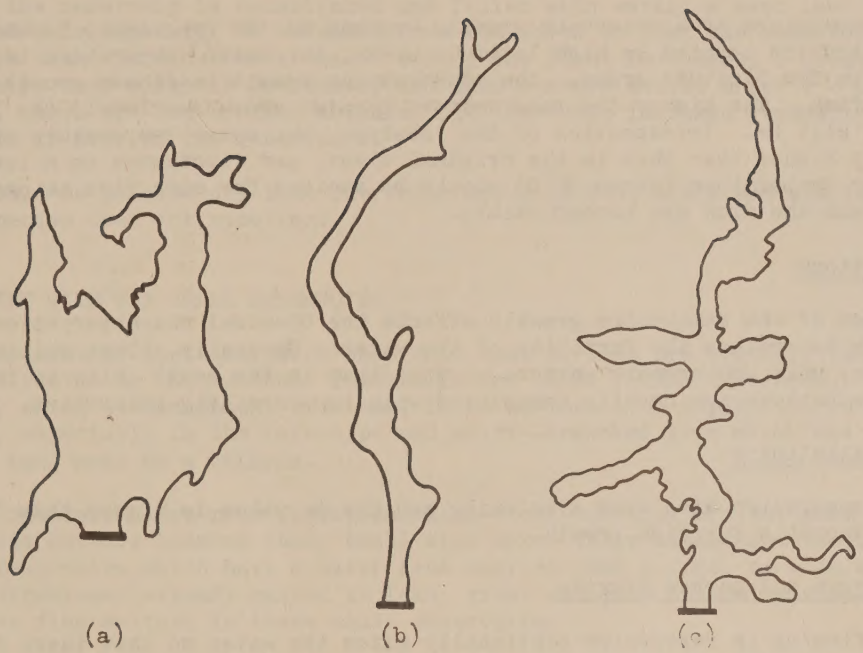


Figure 1: Shape of reservoirs

Multi-branched type reservoirs have a large number of bays and coves and a long shore line, so that the water is in contact with large areas of land; therefore more nutrients flow into the water from the surrounding land, except in highly eroded areas, and the water is thus more fertile in natural fish food organisms. This situation is advantageous to fish growth, and fish production is comparatively high.

Water level

The water level can change greatly in the reservoirs, and this directly affects the water surface area of the reservoirs. On the one hand, during the high water level period, a large land area of the reservoirs will be immersed by the water, the nutrients in the inundated earth will be dissolved and the water becomes more fertile. On the other hand, during the low water level period, much of the land in the reservoir will be exposed again, the organic matter is decomposed and the fertility of the land increased. However, the vast area exposed by the low water adversely affects the growth of aquatic plants and animals, and may destroy the spawning grounds of the fish. But, if conditions are favourable, this exposed land can be used for agriculture or for grazing of animals. Such use may increase the productivity for fisheries.

Water movement

The rate of water flow in reservoirs is obviously slower than in rivers, and it changes according to utilization requirements. In reservoirs used mainly for power generation, the water flows all year. In reservoirs used mainly for irrigation, the water flows fast when the flood period arrives and when the water is used for irrigation. Flowing water helps to increase oxygen content. The water temperature, amount of oxygen content and nutrient concentrations do not change much at different depths of water, especially in the smaller reservoirs. But the water flowing out also carries away with it a large amount of plankton and nutrients. This is disadvantageous to fish culture.

Water temperature

The water temperature of a reservoir greatly depends on its geographic location and altitude. In reservoirs located in high latitude areas, the water temperature is lower than of those located in low latitude areas. Low temperatures result in slower growth of food organisms and of fish. The higher the reservoir is located above sea level, the lower the water temperature will be. Irrespective of the location, the water temperature of the reservoir is distinctly higher than that in the original river, and fluctuates in a less wide range. High water temperature (above 30°C) should be avoided for most fish as oxygen in the water is reduced and the fish are uncomfortable.

Bottom conditions

The soil types of the reservoirs greatly affects the chemical characteristics of the water and directly determines the fertility of the water. Generally, black soil contains abundant nutrients, salt and organic matter, so that loam is the best. Clay is intermediate, and sand and stone bottoms are usually associated with low-fertility reservoirs.

Acidity and alkalinity

Most of the reservoirs have weak alkalinity and the ph value is higher than 7. These conditions are favourable for fish growth.

Dissolved oxygen and carbon dioxide

The current flowing in reservoirs continually mixes the water so that there is sufficient dissolved oxygen from the water surface to the bottom except in the very deepest water layers. However, with little mixing, the amount of dissolved oxygen in the water decreases with increasing depth. On the contrary, the amount of CO_2 content increases with increasing depth. High dissolved oxygen and low CO_2 content are the two important conditions for fish culture in reservoirs.

Nutrition and feed

Normally, reservoirs are very rich in nutrients which include organic matter, nitrate, nitrite, phosphate, silicate, iron and various salts, etc. Most of the nutrient content is usually higher after the flood period.

Table 1

Comparison of content of nutrients of a reservoir before and after flood period

(mg/l)

Time	Organic Matters	Nitrate	Nitrite	Phosphate	Silicate	Iron
Before flood period	3.38	0.043	0.014	0.037	13.91	0.180
After flood period	17.63	0.114	0.006	0.044	20.49	0.014

When the reservoir is established and filled with water, a vast land area will be immersed and nutrients will be released from the earth so that the reservoir water becomes more fertile than the river water was. During the first few years, a great amount of plankton grows quickly, then slightly decreases, and then becomes stable after 7 - 8 years. In the new reservoirs, there are few benthic animals, but they will increase gradually. Aquatic plants are very few in most of the reservoirs.

It should be pointed out that nutrients and fish food kinds and availabilities determine the fish species used for stocking.

4. STARTING WITH THE SMALL RESERVOIRS

The features of the reservoirs show that most of them are suitable for fish culture and propagation including the seasonal reservoirs and those frozen in winter. However, for the time being, owing to management problems, it is advisable to begin fish culture in the small reservoirs, especially in the lake-type and multi-branched type which are located on flat cultivated land near to a village.

Small reservoirs are poor in natural fish stock but they are suitable for semi-intensive and intensive culture because their small size makes their management easy. There are a large number of reservoirs which have a water area smaller than a lake, or even a large pond. The extensive experience already gained in lake, river and pond intensive fish culture can be utilized for fish culture in these small reservoirs.

As a matter of fact, some small reservoirs for intensive culture have an average yearly output of over 750 kg/ha.

5. PREPARATION FOR FISH CULTURE

Before raising fish in the reservoir, some preparatory work must be done:

(i) Setting-up fish screens for preventing fish escaping from the reservoir.

(ii) Clearing the bottom thoroughly.

(iii) Eliminating predatory fish.

(iv) Propagating natural food.

Facilities for preventing escape

In small reservoirs with slow water movement bamboo screens, wood screens (see Fig. 2a(i) and (ii), wire netting (see Fig. 2b) and fibre netting (see Fig. 2c(i) and (ii) are generally used and set up in both the water inlet and outlet, spill way, over-flow hole, etc. If the reservoir is a larger one and water movement is fast, the facilities should be carefully designed and set up according to the different circumstances: the synthetic fibre net is the best choice because it is durable. According to the stocking size of the fingerlings, a screen gap of about 2 - 3 cm and a net mesh size of about 3.5 - 6 cm are usually adopted.

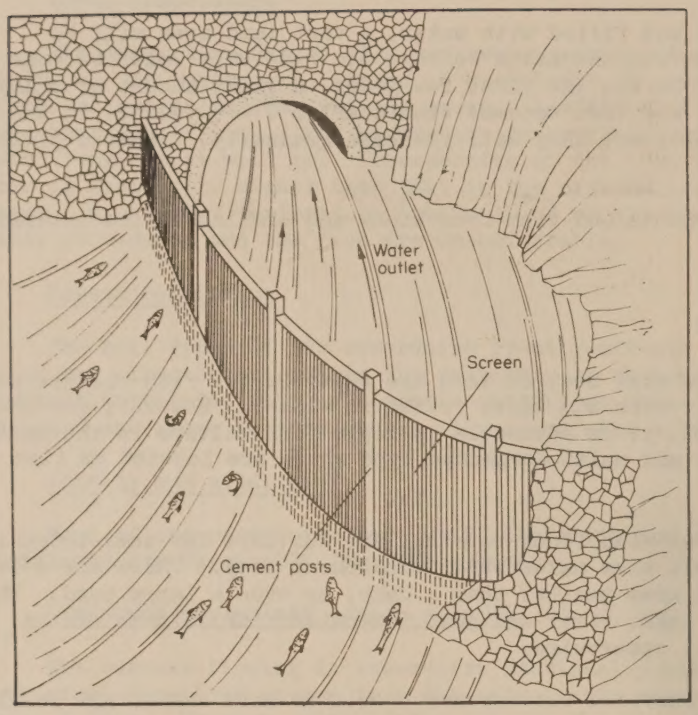


Figure 2a(i): Bamboo and wood screen across reservoir overflow to prevent fish escape

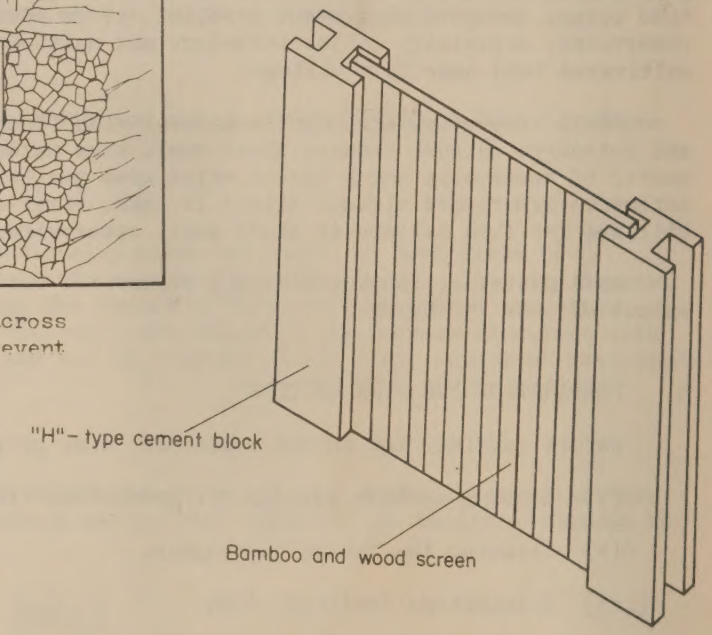


Figure 2a(ii): Diagram showing detailed section of bamboo and wood screen

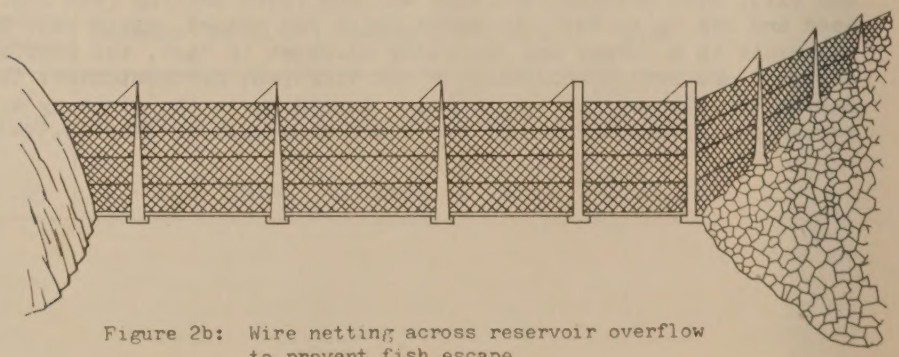


Figure 2b: Wire netting across reservoir overflow to prevent fish escape

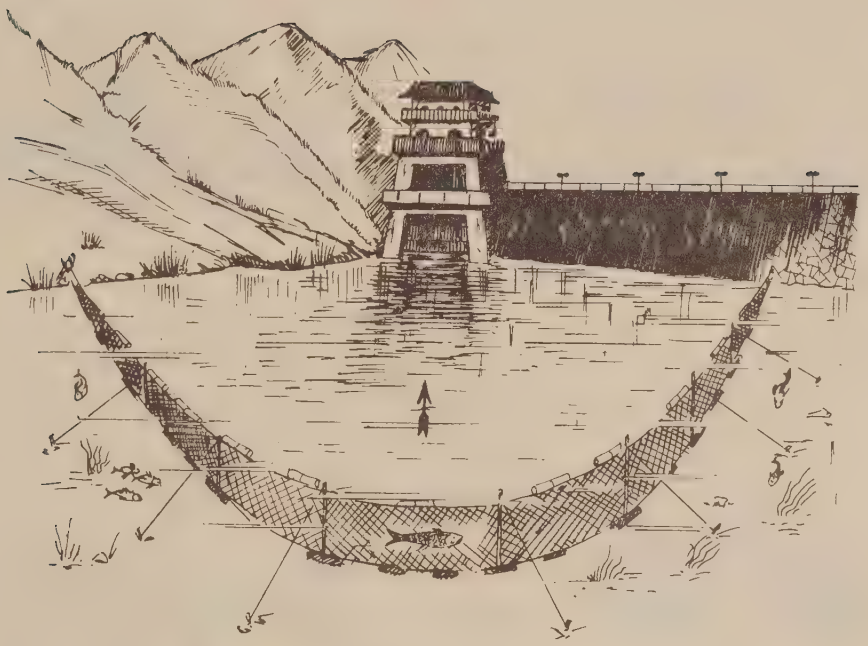


Figure 2c(i): Protecting fish net fixed by anchors

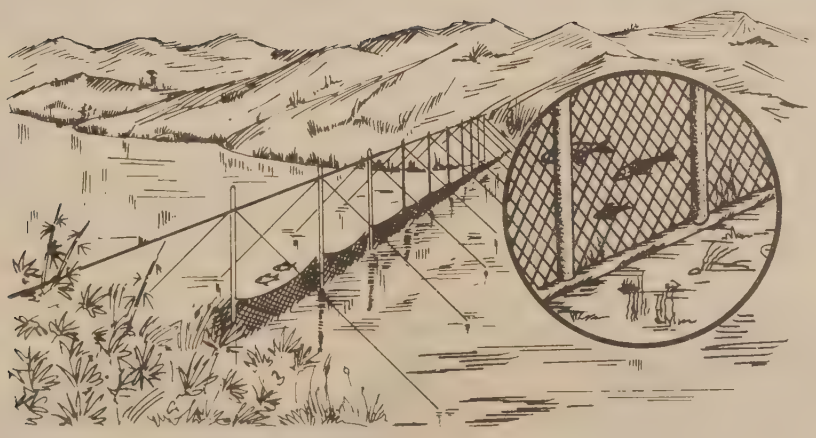


Figure 2c(ii): Protecting fish net fixed by poles driven into the reservoir bed

Clearing and grading the bottom

For the purpose of harvesting, any obstructions such as stumps and stones should be removed and the bottom graded carefully before the reservoir is filled with water or when it has dried out. If it is impossible to clear the bottom of a bigger reservoir completely, at least a part of it - especially the fishing ground - should be well-cleared. Obviously, any obstructions would limit the efficient operation of fishing gear and will greatly affect the ultimate yield of the reservoir. The type or pattern of the clearing will be determined by the kinds of fish present and by the kinds of fishing methods which are to be employed for harvest.

Predatory fish

The most effective way for eliminating the predatory fish and other trash fish is to drain out the reservoir, if this is possible. For small water areas, the fish poisons such as quick lime, tea seed cake, rotenone, bleaching powder, etc., could be used just as in ponds, and it is also advantageous to eliminate bacterial pathogens, parasites and their eggs, and harmful aquatic insects. But whatever material is used, it is inadvisable to stock the fish until the effects of the toxicant have completely disappeared. For a bigger reservoir or even a smaller one which cannot be drained, frequent intensive fishing is necessary. The more completely the predatory fish are eliminated, the greater the quantity of cultivatable fish which can be produced.

In some places it may be advisable to place screens on the inlets to prevent wild fish, especially predators, from entering the reservoir.

Natural feed

The small reservoir usually is of limited depth. Shallow water plants and benthic animals might be introduced and propagated in order to provide additional quantities of natural food for fish. A conglomerate and sand bottom is suitable for snails and mussels, while an earth bottom is suitable for under-water plants and benthic animals introduced from a lake.

6. SPECIES AND SPECIES COMBINATIONS

Species

The kinds of fish which could be raised in a small reservoir are above all dependent on the kinds and quantities of natural foods available. Experience shows that plankton eaters such as silver carp and bighead are most suitable in small reservoirs, especially new ones, because there will be few benthic animals and water plants in it. If there is a good quantity of grass around the reservoir, a herbivorous fish such as grass carp is also a good choice. Tilapia has omnivorous food habits and provides a high productivity, and it may be the best choice in many cases, especially in the tropical and subtropical areas. (In Africa, the most important kinds of fish to stock in reservoirs are the Tilapias, such as Tilapia nilotica, Tilapia melanopleura, Tilapia macrochir, Tilapia andersonii, Tilapia mossambica and Haplochromis spp.). However, the local species which are more suitable to the local conditions should not be overlooked, especially in the cold high regions.

Polyculture (using combinations of species) is a good means to utilize all the available food material in the water and brings about a high production. It is also important to use species that are well-liked by local people or easy to sell in the market.

Figure 3: The common species cultured in reservoirs

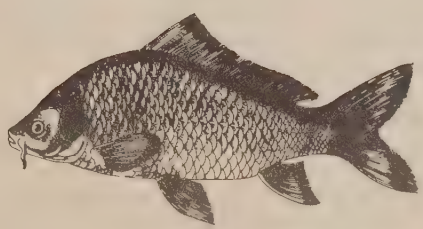
(a) Black Carp

(b) Grass Carp

(d) Bighead

(c) Silver carp

(f) Wuchang Fish



(e) Common Carp

(h) Indian Carp-Rohu

(g) Crucian Carp

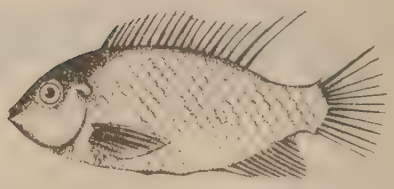
Figure 3 (continued)

(i) Tilapia mossambica (Peters)

(k) Tilapia machrochir

(l) Tilapia sparmanni

(j) Tilapia nilotica



(m) Tilapia melanopleura

Stocking density

The optimum stocking density varies mainly according to the fertility of the water and the growth rate of the fish. In general, if fingerlings are stocked in the early spring and harvested in the winter, the stocking density might be 450-600 fingerlings/ha up to 900-1 500 fingerlings/ha. For example, a reservoir polyculture with the silver carp and bighead might be stocked as follows:

- very fertile water with many predators: 1 200 - 1 500 fingerlings/ha, 13 - 16 cm in length, or 3 000 fingerlings/ha, 10 cm in length
- fertile water with some predators: 750 - 900 fingerlings/ha, 13 cm in length, or 1 800 - 2 250 fingerlings/ha, 10 cm in length
- sterile water with some predators: 450 - 600 fingerlings/ha, 13 cm in length, or 1 200 fingerlings/ha, 10 cm in length

In tropical areas, under normal feeding conditions, the number of Tilapia that can be supported per hectare water area is as follows:

Weight per fish	Number of fish that can be supported per ha
10 g	50 000
30 g	27 000
50 g	20 000
100 g	13 500
150 g	11 000
200 g	9 000
250 g	8 000

The natural conditions of the reservoirs are quite different from one another, and the stocking density should be adjusted according to the practices of the production activities.

Combination of species

Polyculture can bring the production potential of a water body into full play. It is one of the main elements for a bumper harvest. Usually one or two species are cultivated as a major component and are combined with some other species, all of which have different feeding habits. For instance:

- Water rich in plankton: by numbers, 70 - 80 percent silver carp and bighead in majority (silver carp : bighead, 8 : 2 or 7 : 3) combined with grass carp (less than 5 percent) and black carp, Wuchang fish (Magalobrama amblycephala).

- Water rich in grass (aquatic grass and ground grass): 50 percent grass carp, 25 percent silver carp, 15 percent bighead, 10 percent Wuchang fish and common carp.

In some tropical areas the following amounts of Tilapia are recommended for reservoir stocking:

- reservoir of 4 ha and under: not less than 9 kg

- reservoir of 4 - 8 ha: not less than 18 kg

- reservoir of over 8 ha: not less than 27 kg

These amounts are for fingerlings of T. melanopleura, T. macrochir and T. andersonii in roughly equal proportions.

The following combination of stock can be adopted in some Asian areas:

(a) Tilapia mossambica and Cyprinus

(b) Aristichtyus nobilis and C. carpio

(c) T. mossambica, A. nobilis and C. carpio

(d) Chanos chanos and C. carpio

Table 2

General stocking proportion of carps
in small reservoirs

(%)

Species	Fertile Water	Sterile Water
Bighead	50	60
Silver Carp	30	20
Grass Carp	5	10
Common Carp & Bream etc.	15	10

According to the existing conditions, the different species must be well-proportioned in polyculture, because any irrational proportion could inhibit the growth of some kinds of fish and eventually decrease the total production.

Adjusting the stocking density and species' proportion

The stocking density and the proportions of different species determine the growth rate and the production output. After one year of rearing, if the fish growth is greater than normal, this indicates the stocking density is too low; and if the growth rate is lower than normal the stocking density is too high. Therefore the stocking density should be adjusted in the following year. For example, in tropical areas, Tilapia at 8 months old is about 150 - 250 g, and common carp about 350 g. The Mrigal (Cirrhinus mrigala) is reported to grow 20 - 25 cm in the first year, and 35 cm in the second. Similarly, observing the growth rates and the yields of different species of fish might be helpful in determining the ideal stocking densities and species' combination proportions.

Table 3

Relationship between ages, length and weight of Silver Carp, Bighead and Mrigal

(length: cm; weight: kg)

Ages (years)	Silver Carp		Bighead		Mrigal	
	Length	Weight	Length	Weight	Length	Weight
1	15	0.067	17	0.110	29	0.245
2	33	0.601	37	0.802	51	1.512
3	48	1.701	54	2.71	67	3.62
4	54	2.815	65	5.20	79	6.32
5	60	4.20	75	7.50	86	8.03
6	65	4.50	80	10.10	89	8.96
7	67	5.05	82	11.10	91	9.71
8	72	-	88	12.30	92	10.09

7. FINGERLINGS

Choice of large, healthy and similar-sized fingerlings for stocking is a key factor in raising the survival rate and gaining a high yield. Small fingerlings will be easy prey for predatory fish, and they can escape from the reservoir through the fish screens.

Fingerlings should be active, of a uniform size, brightly-coloured, completely scaled, have a stout body and be good swimmers against currents. They should be able to dive to the bottom of the water immediately whenever they are disturbed.

How to obtain fingerlings

Fish culture in reservoirs needs an abundance of large-size fingerlings of good quality. The best way to solve this problem is through self-reliance, by raising one's own fingerlings. If it is possible, the fry and fingerling ponds should be established near the reservoir. If the reservoir is the branched type, it may be best to block off one or more arms or bays for

fingerling ponds. If these are not possible, then a good idea is to set up some net cages in the reservoir for rearing fry and fingerlings. In many cases smaller reservoirs could be used directly for raising the fingerlings. When the fingerlings grow large enough, the required amount could be left in the reservoir to be raised to table-size. The remaining fingerlings could be used to meet other requirements, for example, selling to farmers in the neighbourhood or stocked into nearby reservoirs.

Obtaining the fingerlings from fish farms or fish breeding stations is more convenient, but great attention should be paid to the quality of fish supplied, and care in transportation. The cost of the fingerlings might be high, and supplies may not always be available when required.

Rearing the fry and fingerlings

The ideal characteristics of fry and fingerling ponds established near the reservoirs, the rearing methods and pond management are almost the same as those of pond culture.

The brood fish may be collected from the larger-sized reservoirs, or from the rivers which are connected with them. If the brood fish are not fully mature, it is necessary to rear them carefully in the ponds for 1 - 2 years until they become fully mature. Then means of artificial propagation could be adopted. The methods of rearing brood fish (e.g., correct quantity of suitable food, water quality, etc.) are extremely important, and it must be stressed that these obviously affect the degree of maturity, quantity, hatching rate and the survival rate of fry.

Time for stocking

Practice shows that the most suitable time for stocking fingerlings is in the winter or early spring. At that time the water temperature is relatively low, the predatory fish are not so active, and the water exchange in the reservoir is slow. Thus it is the best time to achieve the highest survival rate of fingerlings. Stocking the fingerlings during the flood period and during the time when the predatory fish are very active must be avoided. The specific stocking time should be selected in accordance with the local conditions.

Location for stocking

The features of a suitable place for stocking include: upstream of the reservoir, in shallow water where there is sufficient food, shelter from the wind, and towards the sunlight. It should be borne in mind that the fingerlings should not be directly stocked in places near the outlet, spill-way and over-flow hole, or in the centre of the reservoir. Also, they should be stocked on a sunny day, not when it is raining or snowing, and the fingerlings should not be poured roughly into the reservoir but by gently putting the container into the water, tipping it a little, and letting the fingerlings swim out by themselves. Before transferring the fingerlings from the container into the reservoir, it should be ascertained that there is no great difference in temperature between the two water environments. If there is, this can be overcome by gradually bringing the water temperature of the container to that of the reservoir.

The fingerlings should be disinfected before stocking so as to lessen the risk of fish diseases, especially when the fingerlings are supplied from outside. For example, bleaching powder (10 ppm) and copper sulphate (8 ppm) can be used either singularly or combined, and the fish soaked in the solution for a bathing time of about 20 - 30 minutes, at a water temperature of 10° - 15°C. The bathing time should be less when the solution temperature is higher.

8. FEEDING THE FISH IN RESERVOIRS

A smaller reservoir is more suitable for semi-intensive and intensive culture than a larger one. The adult fish in a smaller reservoir can be reared by the same methods used in fish ponds.

Fertilizer and feed are the basic materials of fish culture. Organic manure could be applied to the water in order to multiply the plankton. Various aquatic weeds and tender gramineous plants can be used for food for grass carp. Some by-products of the food industry such as bean cakes, peanut residue cakes, sugar dregs, rice bran, soybean remains, wine residues, grain-bran cakes, etc., and other artificial feeds are also indispensable as a supplement. The stocking rate may be somewhat higher under good feeding conditions. The availability of food supply should also be taken into account in the adjustment of the stocking densities and species' proportion in polyculture.

Feed and fertilizers should be given with frequent applications but with low amounts in each application. They should be changed in accordance with changes in weather conditions, water quality, the activities of the fish, and the changes of season. Overfeeding may result in an accumulation of fermented and decomposed residues which cause the water quality to deteriorate whereas underfeeding may lead to food shortages which will decrease the fish growth rate.

The most appropriate fertilization and high stocking rate are key factors for high production.

Sources of fertilizer and food

Successful intensive and semi-intensive fish culture in the small reservoirs is partly dependent on regular supplies of fertilizers and supplementary feeds. Feed cost is usually the largest component of the production costs in fish culture. Not only because of cost, but also because of unreliable supplies, great attention should be paid to establishing the feed production bases at or near the reservoir as an integral part of the fish culture operation.

Fertilizer and feed production could be undertaken through intensification of agriculture and animal husbandry adjacent to water areas, and in low-lying lands close to the shores. Pigs, sheep, ducks, geese, vegetables, grass, etc., could be raised in these areas and the organic manure can be used to increase the fertility of water bodies, or for directly feeding the fish. Integrated fish-crop-livestock and other sideline occupations can be adopted to achieve all-round development and also to diversify the economy and production. With the addition of an adequate number of nursery ponds and fingerling ponds, a complete and sound production system will be established, which could be carried out stage by stage.

Preliminary criteria are important:

- the fry and fingerling pond area should be at least 10 - 15 percent of the total water area;
- the feed production base area should be at least 50 percent more than the total fry and fingerling pond area;
- at least 15 - 30 pigs, 1 500 - 3 000 chickens/ducks or 3 cows per 1 ha of cultured area should be raised.

9. MANAGEMENT

There are four important factors in the management of reservoir fish culture:

1. Building-up and perfecting the forces of the profession

There should be certain persons in charge of the management, who inspect the reservoir regularly and observe the water quality - especially the water colour - and fish behaviour - especially their movements, so that timely treatment can be taken in case of any abnormal conditions. Low oxygen resulting from over-fertilization and/or high water temperature is the most frequently encountered problem.

2. Guard against the escape of fish

The fish screens, nets and other facilities should be regularly inspected and repaired immediately. In the event of heavy rain and during flooding, much attention must be paid to avoid any escape from the overflow.

3. Additional feeding and fertilization

When the water quality is such that the waters are much less fertile, additional amounts of fertilizers and food should be supplied.

4. Record, analyse and sum up the experience

Continuously record and analyze the hydrological data, fish movement, feeding and growth conditions so that this information can be used to contribute to further development and "fine-tuning" of the fish culture operation. To regularly evaluate will provide an accumulation of experience which is the key factor for rational management of the reservoir.

10. HARVESTING

When the fish grow up to table size, harvesting usually is accomplished by means of catching a large percentage of the stock in a short time. According to the bottom condition, seine nets, set nets and gill nets can be used for harvesting:

Seine net

In the smaller reservoirs with a graded bottom, the seine net is used for harvesting. It is used in the same way as harvesting in fish ponds. Usually harvesting is carried out during the dry season or in the winter when the fish grow slowly. The seine net height is 1.5 times the water depth, the bunt height 2 times the water depth, and the net length 1.2 - 1.5 times the width of the reservoir. The net should be dragged from upstream to downstream, and then the fish are taken out of the bunt.

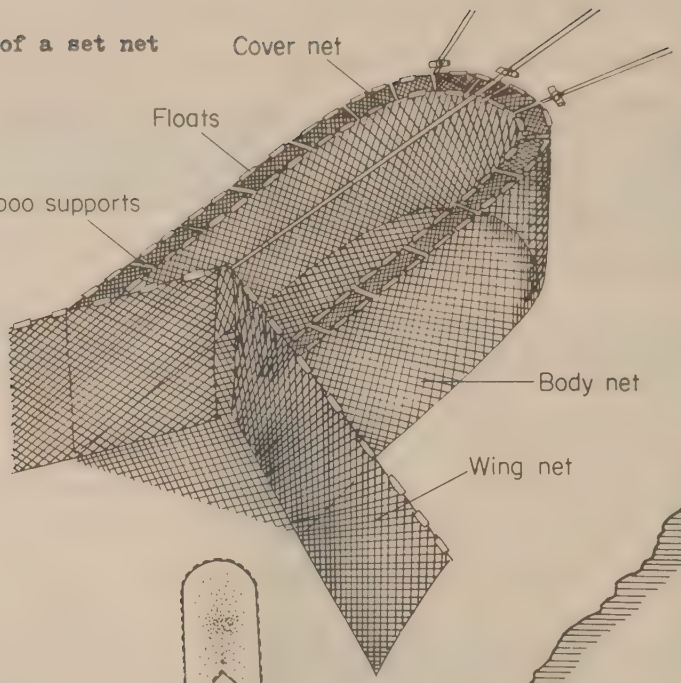
Set net

If the bottom condition is not suitable for a seine net, the set net can be used and usually combined with driving fish towards the set net at one end of the reservoir with boatmen beating the water. As the fish move forward together, a net is set behind the boats to prevent the fish from returning (and therefore having to repeat the process) so the fish have thus been concentrated at one end of the reservoir and finally caught by the set net.

Encircling net and gill net

These can also be used when the fish have been concentrated as described above.

Figure 4a(i): Diagram of a set net



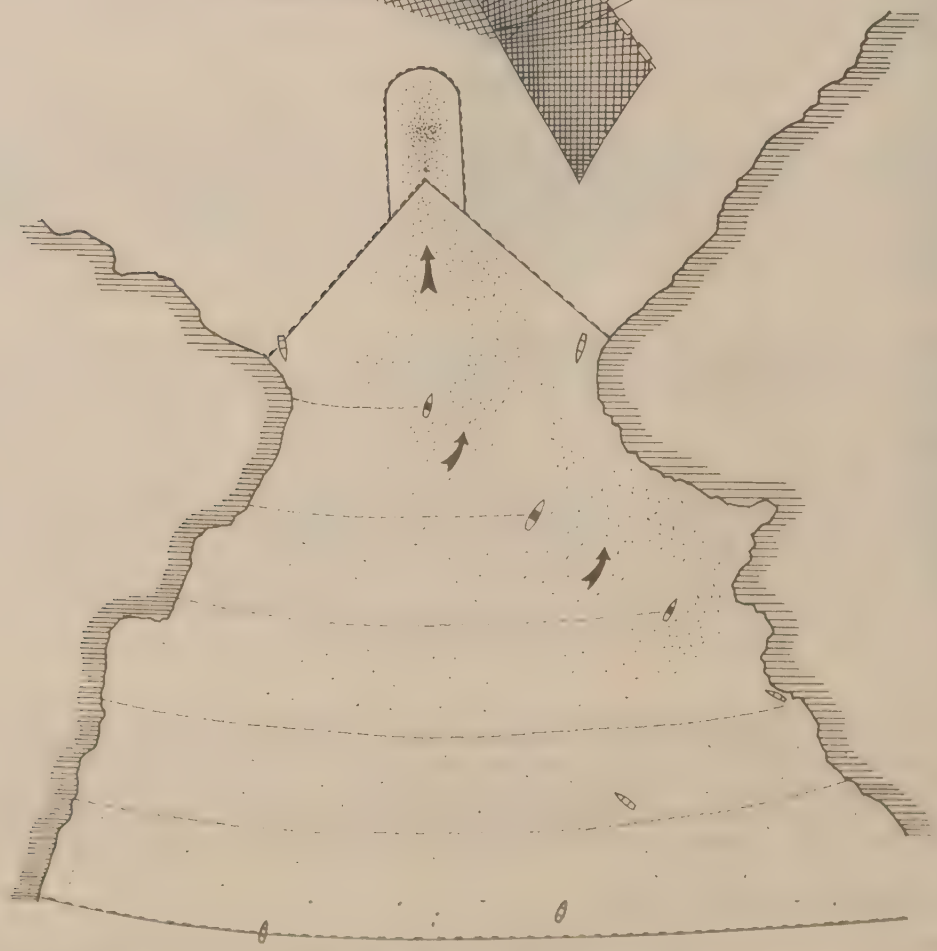


Figure 4a(ii): Diagram showing successive positions of blocking nets concentrating fish for capture by set net

Figure 4b: Fishing with a seine net

11. UTILIZATION OF MEDIUM AND LARGE RESERVOIRS

Large and medium reservoirs may not only be used for stocking, but also for semi-intensive and intensive fish culture. As the saying "divide and rule", the shallow bays and coves of the reservoirs can be blocked off by nets or screens to serve as nurseries or for fish breeding areas, and for rearing fry and fingerlings to stock the water bodies; some of them can also be used for intensive culture of adult fish.

Furthermore, if the bays and coves are blocked off by different mesh-size nets or different gaps in screens, the so-called "reservoir multi-grade conveyer culture" could be carried out. The fry and fingerlings can be divided into different grades according to their size, and raised in the separate blocked areas, for example:

The first grade netting area

In a 1 - 5 ha water area, water depth about 2 - 4 metres, blocked by a kind of synthetic fibre net with 32 - 39 mesh/2.54 cm (1 inch), fry are directly stocked after they are hatched with a stocking rate of 1.5 - 1.8 million/ha.

The second grade netting area

About 10 ha, water depth less than 10 m, blocked by net with 6 - 8 mesh/2.54 cm (1 inch): when the fry grow to fingerlings of about 3.5 cm in length, they can be transferred to this area with a stocking density of about 300 - 450 000/ha.

The third grade netting area

More than 20 ha, water depth about 10 m, blocked by net with stretch mesh size about 3 - 4 cm for raising the large-size fingerlings from the second grade netting area with stocking density of about 15 - 45 000/ha.

12. BAY AND COVE CULTURE

To utilize the bays and coves of the reservoirs for culture which are located in the area exposed by the low water and blocked by dikes, these can be filled during the high water level period and then separated from the reservoir for raising the fingerlings or adult fish; this method is the so-called "bay and cove culture".

Bays and coves satisfactory for fish culture should have a narrow water outlet, a large diameter, flat bottom, south-oriented direction to provide sufficient sunlight, and some small mountain torrents flowing into it. Experience shows that a suitable bay for raising fry may cover 1 - 5 ha, and for fingerlings about 3.5 - 8 ha. This size is convenient for management and for gaining high production.

The dike is usually constructed of stone and earth. The shallower bay can be blocked-off by only a simple earth dike. The dike should have a height of more than 1.5 m above normal water level, and facilities for preventing fish escape should be set up. All these arrangements should be made during the dry season.

It is necessary to clear the bottom and eliminate predators before filling.

A certain amount of base manure should be sprayed into the bay or cove before fry or fingerling stocking in order to encourage the multiplication of the natural food in the bay or cove. During the fish growth period, especially during the time when the water level becomes higher, adequate additional food is needed. The rearing methods and bay and cove management are very similar to those used in pond, lake and reservoir culture.

13. DEVELOPMENT

Intensive and semi-intensive fish culture in reservoirs is a relatively new and emerging field in aquaculture. It still has to be further developed. In many cases, pond and lake water areas are being reduced as a result of competition with other requirements for land and water, but reservoir water areas have increased significantly over the years all over the world. Fish culture in reservoirs has a great potential for increasing fish production.

Net cage culture in the reservoirs and utilization of the water of the reservoirs for gravity running-water high-density fish culture has presented a very bright future even in its experimental stage.

The fishery, including both fishing and fish culture in a reservoir, especially a new one, should be developed on the basis of an orderly economic and scientifically conceived programme. From this point of view, it is therefore of extreme importance that fishery experts and/or extension workers should be involved in the earliest stages of planning for the utilization of reservoirs. In a carefully planned and executed reservoir system, some requirements for fish culture, such as bottom cleaning, fish pens/screens, fry and fingerling ponds, netting and dikes, may often be constructed at surprisingly low additional cost, and the additional cost may be recovered many times over from the resulting fish culture production.

It should be noted that the success of fish culture in the reservoirs is highly dependent on the effectiveness of the authorities responsible for administering and servicing the area.

Reservoirs, man-made lakes, offer unusual opportunities for fish culture and through man's efforts must be turned into a reality, and supply more and more protein-rich food for mankind.